AMENDMENTS TO THE SPECIFICATION

Please amend the title on page 4, line 5 as follows:

BRIEF DESCRIPTION OF THE <u>DRAWINGS</u> ~~DRAWING~~

Page 4, line 15, please add as follows:

<u>Figure 6 is a k-ω plot constructed according to the present invention, showing acoustic ridges, wherein the fluid flowing in the pipe is water with entrained air.</u>

Page 5, lines 16-20, please amend as follows:

The controller module 22 controls and coordinates the operation of the modules 14, 18, 20 and 32. As shown, the signals along lines 14a, 18a are provided directly to the controller module 22, although the scope of the invention is intended to include embodiments in which the signals along lines 14a, 18a are provided directly to the dissolved air/gas determination processor module 20. <u>The bleed line control module 32 controls the bleed valve 28 and boost pump 30 (see Fig. 2) in response to a signal from the controller module 22.</u>

Page 6, lines 8-10, please amend as follows:

The device 10 also includes a bleed line control module <u>32</u> for controlling the bleeding off of the portion of the fluid or process mixture from the process line via the bleed valve 28 and the reinjection of the same back to the process line 12 via the boost pump 30.

Page 6, line 25 through page 7, line 5, please amend as follows:

The present invention uses the speed at which sound propagates within a conduit to measure entrained air in slurries. This approach may be used with any technique that measures the sound speed of a fluid or process mixture. However, it is particularly synergistic with sonar based volumetric flow meters such as described in aforementioned U.S. Patent Application, Serial No. 10/007,736 (CiDRA's Docket No. CC-0122A), <u>now US 6,889,562,</u> in that the sound speed measurement, and thus gas volume fraction measurement, can be accomplished using the same hardware as that required for the volumetric flow measurement. It should be noted, however, that the gas volume fraction (GVF) measurement could be performed independently of

a volumetric flow measurement, and would have utility as an important process measurement in isolation or in conjunction with other process measurements.

Page 7, lines 6-16, please amend as follows:

Firstly, the sound speed may be measured as described in aforementioned U.S. Patent Applications, Serial No. 09/344,094 (CiDRA's Docket No. CC-0066A), now US 6,354,147, Serial No. 10/007,749 (CiDRA's Docket No. CC-0066B), now US 6,732,575, U.S. Patent Application, Serial No. 10/349,716 filed January 23, 2003 (Cidra's Docket No. CC-0579) and/or U.S. Patent Application, Serial No. 10/376,427 filed February 26, 2003 (Cidra's Docket No. CC-0596), all incorporated herein by reference, using an array of unsteady pressure transducers. For a two component mixture, utilizing relations described in U.S. Patent Applications, Serial No. 09/344,094 (CiDRA's Docket No. CC-0066A), now US 6,354,147, and/or Serial No. 10/007,749 (CiDRA's Docket No. CC-0066B), now US 6,732,575, knowledge of the density and sound speed of the two components and the compliance properties of the conduit or pipe, the measured sound speed can be used to determine the volumetric phase fraction of the two components.

Page 9, lines 3-15, please amend as follows:

Fig. 4 also shows that for the region of interest, from roughly 1% entrained air to roughly 5% entrained air, mixture sound speeds (a_{mix}) are quite low compared to the liquid-only sound speeds. In the example shown above, the sound speed of the pure water and the 5% pulp slurry were calculated, based on reasonable estimates of the constituent densities and compressibilities, to be 1524 m/s and 1541 m/s, respectively. The sound speed of these mixtures with 1% to 5% entrained air at typical operating pressure (1 atm to 4 atms) are on the order of 100 m/sec. The implication of these low sound speeds is that the mixture sound speed could be accurately determined with an array of sensors, i.e. using the methodology described in aforementioned U.S. Patent Applications, Serial No. 09/344,094 (CiDRA's Docket No. CC-0066A), now US 6,354,147, and/or Serial No. 10/007,749 (CiDRA's Docket No. CC-0066B), now US 6,732,575, with an aperture that is similar, or identical, to an array of sensors that would be suitable to determine the convection velocity, using the methodology described in aforementioned U.S. Patent Application, Serial No. 10/007,736 (CiDRA's Docket No. CC-0122A), now US 6,889,562, which is incorporated herein by reference.

Page 10, lines 16-22, please amend as follows:

As shown in ~~Figure~~ Fig. 3, the sonar meter measures the speed at which acoustic wave propagating in the process piping to determine the amount of entrained air in the process line. The acoustic wave can be generated by a pump or other device disposed in the piping system, or generated simply by the mixture/fluid flowing through the pipe, all of which provide a passive acoustic source. Alternatively, the sonar flow meter includes an active acoustic source that injects an acoustic wave into the flow such as by compressing, vibrating and/or tapping the pipe, to name a few examples.

Page 11, lines 21-28, please amend as follows:

Ultrasonic meters typically operate in 100 Khz to several Mhz frequency range. For these meters, entrained air bubbles have length scales on the same order as the acoustic waves generated by the ultrasonic meters. They ~~The~~ posed several problems. Firstly, the bubbles scatter the ultrasonic waves, impairing the ability of the ultrasonic meter to perform a sound speed measurement. Also, ultrasonic meters rely on information derived from only a small fraction of the cross sectional area of the pipe to be representative of the entire cross section, an assumption that breaks down for flows with inhogenieties on the same length scale as the ultrasonic wavelength.

Page 12, line 22 through page 13, line 8, please amend as follows:

Figure 6 shows a k-ω plot generated for acoustic sound field recorded from water flowing at a rate of 240 gpm containing ~2% entrained air by volume in a 3 in, schedule 10, stainless steel pipe. The k-ω plot was constructed using data from an array of strain-based sensors attached to the outside of the pipe. Two acoustic ridges are clearly evident. Based on the slopes of the acoustic ridges, the sound speed ~~for this~~ for this mixture was 330 ft/sec (100m/s), consistent with that predicted by the Wood equation. Note that adding 2% air by volume reduces the sound speed of the bubbly mixture to less than 10% of the sound speed of single phase water. Fig. ~~15~~ 7 illustrates a schematic drawing of one embodiment of the present invention. The apparatus 210 includes a sensing device ~~16~~ 216 comprising an array of pressure sensors (or transducers) ~~18-21~~ 218-221 spaced axially along the outer surface ~~22~~ 222 of a pipe ~~14~~

214, having a process flow propagating therein, similar to that described hereinbefore. The pressure sensors measure the unsteady pressures produced by acoustical disturbances within the pipe, which are indicative of the SOS propagating through the mixture ~~12~~ 212. The output signals ($P_1 - P_N$) of the pressure sensors ~~18-21~~ 218-221 are provided to the processor 224, which processes the pressure measurement data and determines the speed of sound, gas volume fraction (GVF) and other parameters of the flow as described hereinbefore.

Page 13, lines 9-16, please amend as follows:

In an embodiment of the present invention shown in Fig. 7, the apparatus 210, similar to the arrays 24,26 of Fig. ~~1~~ 2, has at least two pressure sensors 218-221 disposed axially along the pipe 214 for measuring the unsteady pressure P_1-P_N of the mixture 212 flowing therethrough. The speed of sound propagating through the flow 212 is derived by interpreting the unsteady pressure field within the process piping 214 (e.g., the bleed line 16 and primary process line 12) using multiple transducers displaced axially over ~ 2 diameters in length. The flow measurements can be performed using ported pressure transducers or clamp-on, strain-based sensors.

Page 13, lines 20-28, please amend as follows:

Generally, the apparatus 210 measures unsteady pressures created by acoustical disturbances propagating through the flow 212 to determine the speed of sound (SOS) propagating through the flow. Knowing or measuring the pressure and/or temperature of the flow by a pressure sensor 23 and a temperature sensor 24, respectively, and the speed of sound of the acoustical disturbances, the processing unit 224 can determine the gas volume fraction of the mixture, similar to that shown in U.S. Patent Application Serial No. 10/349,716 (Cidra Docket No. CC-0579), filed January 21, 2003, U.S. Patent Application Serial No. 10/376,427 (Cidra Docket No. CC-0596), filed February 26, 2003, and U.S. Provisional Patent Application Serial No. 60/528,802 (Cidra Docket No. CC-0685), filed December 11, 2003 which are all incorporated herein by reference.

Page 14, lines 1 – 7, please amend as follows:

The apparatus 210 in Fig. ~~210~~ 7 also contemplates providing one or more acoustic sources 227 to enable the measurement of the speed of sound propagating through the flow for instances of acoustically quiet flow. The acoustic sources may be disposed at the input end ~~of~~ or output end of the array of sensors 218-221, or at both ends as shown. One should appreciate that in most instances the acoustics sources are not necessary and the apparatus passively detects the acoustic ridge provided in the flow 212. The passive noise includes noise generated by pumps, valves, motors, and the turbulent mixture itself.

Page 14, lines 8 - 22, please amend as follows:

The apparatus 210 of the present invention may be configured and programmed to measure and process the detected unsteady pressures $P_1(t) – P_N(t)$ created by acoustic waves propagating through the mixture to determine the SOS through the flow 212 in the pipe 214. One such apparatus 310 is shown in Fig. 8 that measures the speed of sound (SOS) of one-dimensional sound waves propagating through the mixture to determine the gas volume fraction ~~o f~~ of the mixture. It is known that sound propagates through various mediums at various speeds in such fields as SONAR and RADAR fields. The speed of sound propagating through the pipe and mixture 212 may be determined using a number of known techniques, such as those set forth in U.S. Patent Application Serial No. 09/344,094, entitled "Fluid Parameter Measurement in Pipes Using Acoustic Pressures", filed June 25, 1999, now US 6,354,147; U.S. Patent Application Serial No. 09/729,994, filed December 4, 2002, now US 6,609,069; U.S. Patent Application Serial No. 09/997,221, filed November 28, 2001, now US 6,587,798; and U.S. Patent Application Serial No. 10/007,749, entitled "Fluid Parameter Measurement in Pipes Using Acoustic Pressures", filed November 7, 2001, now US 6,732,575, each of which are incorporated herein by reference.

Page 14, line 27 through page 15 line 11, please amend as follows:

As shown in Fig. 8, an apparatus 310 embodying the present invention has a sensing device 150 including an array of at least two acoustic pressure sensors 115,116, located at three locations x_1,x_2 axially along the pipe 214. One will appreciate that the sensor array may include more than two pressure sensors as depicted by pressure sensors 117,118 at location x_3,x_N. The

pressure generated by the acoustic waves may be measured through pressure sensors 115 - 118. The pressure sensors ~~215 - 218~~ 115-118 provide pressure time-varying signals $P_1(t),P_2(t),P_3(t),P_N(t)$ on lines 120,121,122,123 to a signal processing unit 130 to known Fast Fourier Transform (FFT) logics 126,127,128,129, respectively. The FFT logics 126 - 129 calculate the Fourier transform of the time-based input signals $P_1(t)$ - $P_N(t)$ and provide complex frequency domain (or frequency based) signals $P_1(\omega),P_2(\omega),P_3(\omega),P_N(\omega)$ on lines 132,133,134,135 indicative of the frequency content of the input signals. Instead of FFT's, any other technique for obtaining the frequency domain characteristics of the signals $P_1(t)$ - $P_N(t)$, may be used. For example, the cross-spectral density and the power spectral density may be used to form a frequency domain transfer functions (or frequency response or ratios) discussed hereinafter.

Page 15, lines 12 – 16, please amend as follows:

The frequency signals $P_1(\omega)$ - $P_N(\omega)$ are fed to an array processing unit 138, similar to the array processing unit 223, which provides a signal to line ~~40~~ 140 indicative of the speed of sound of the mixture a_{mix}, discussed more hereinafter. The a_{mix} signal, temperature signal (from temperature sensor 4), and pressure signal (from pressure sensor 3) is provided to an entrained gas processing unit 142, similar to the processing unit 225. ~~, which~~ The processing unit 142 converts a_{mix} to a percent composition of a mixture and provides a gas volume fraction or %Comp signal to line ~~244~~ 144 indicative thereof (as discussed hereinafter).

Page 15, line 22 through page 16 line 1, please amend as follows:

One such technique of determining the speed of sound propagating through the flow 212 is using array processing techniques to define an acoustic ridge in the k-ω plane as shown in Fig. ~~9~~ 6. The slope of the acoustic ridge is indicative of the speed of sound propagating through the flow 212. This technique is similar to that described in U.S. Patent No. 6,587,798 filed November 28, 2001, titled "Method and System for Determining The Speed of Sound in a Fluid Within a Conduit", which is incorporated herein by reference. The speed of sound (SOS) is determined by applying sonar arraying processing techniques to determine the speed at which the one dimensional acoustic waves propagate past the axial array of unsteady pressure measurements distributed along the pipe 214.

Page 16, line 9 - 16, please amend as follows:

The flow meter of the present invention uses known array processing techniques, in particular the Minimum Variance, Distortionless Response or other adaptive array processing techniques (MVDR, Music, or Capon technique), to identify pressure fluctuations, which convect with the materials flowing in a conduit and accurately ascertain the velocity, and thus the flow rate, of said material. These processing techniques utilize the covariance between multiple sensors 218 - 221 at a plurality of frequencies to identify signals that behave according to a given assumed model; in the case of the apparatus 310, a model, which represents pressure variations ~~220~~ convecting at a constant speed across the pressure sensors comprising the sensing device 216. ~~flow meter monitoring head 212.~~

Page 17, line 22 through page 18, line 4, please amend as follows:

In certain embodiments of the present invention a piezo-electronic pressure transducer may be used as one or more of the pressure sensors 218-221 and it may measure the unsteady (or dynamic or ac) pressure variations inside the pipe 214 by measuring the pressure levels inside of the pipe 214. ~~14.~~ In an embodiment of the present invention the sensors 218-221 comprise pressure sensors manufactured by PCB Piezotronics. In one pressure sensor there are integrated circuit piezoelectric voltage mode-type sensors that feature built-in microelectronic amplifiers, and convert the high-impedance charge into a low-impedance voltage output. Specifically, a Model 106B manufactured by PCB Piezotronics is used which is a high sensitivity, acceleration compensated integrated circuit piezoelectric quartz pressure sensor suitable for measuring low pressure acoustic phenomena in hydraulic and pneumatic systems. It has the unique capability to measure small pressure changes of less than 0.001 psi under high static conditions. The 106B has a 300 mV/psi sensitivity and a resolution of 91 dB (0.0001 psi).

Page 18, line 22 through page 19, line 6, please amend as follows:

The pressure sensors 218-221 described herein may be any type of pressure sensor, capable of measuring the unsteady (or ac or dynamic) pressures within a pipe, such as piezoelectric, optical, thermal, capacitive, inductive, resistive (e.g., Wheatstone bridge), accelerometers (or geophones), velocity measuring devices, displacement measuring devices,

etc. If optical pressure sensors are used, the sensors 218-221 may be Bragg grating based pressure sensors, such as that described in US Patent Application, Serial No. 08/925,598, entitled " High Sensitivity Fiber Optic Pressure Sensor For Use In Harsh Environments", filed Sept. 8, 1997, now U.S. Patent 6,016,702. Alternatively, the sensors ~~23~~ 218-221 may be electrical or optical strain gages attached to or embedded in the outer or inner wall of the pipe which measure pipe wall strain, including microphones, hydrophones, or any other sensor capable of measuring the unsteady pressures within the pipe 214. In an embodiment of the present invention that utilizes fiber optics as the pressure ~~sensors218-221~~ sensors 218-221, they may be connected individually or may be multiplexed along one or more optical fibers using wavelength division multiplexing (WDM), time division multiplexing (TDM), or any other optical multiplexing techniques.

Page 19, lines 20-28, please amend as follows:

For any of the embodiments described herein, the pressure sensors, including electrical strain gages, optical fibers and/or gratings among others as described herein, may be attached to the pipe by adhesive, glue, epoxy, tape or other suitable attachment means to ensure suitable contact between the sensor and the pipe ~~212~~ 214. The sensors may alternatively be removable or permanently attached via known mechanical techniques such as mechanical fastener, spring loaded, clamped, clam shell arrangement, strapping or other equivalents. Alternatively, the strain gages, including optical fibers and/or gratings, may be embedded in a composite pipe. If desired, for certain applications, the gratings may be detached from (or strain or acoustically isolated from) the pipe 212 if desired.

Page 20, lines 1-3, please amend as follows:

It is also within the scope of the present invention that any other strain sensing technique may be used to measure the variations in strain in the pipe, such as highly sensitive piezoelectric, electronic or electric, strain gages attached to or embedded in the pipe 214. ~~212.~~